AD-A182 597 A COLLABORATIVE STUDY OF PLASMA IRREGULARITIES FROM THE HILAT SATELLITE(U) TEXAS UNIV AT DALLAS RICHARDSON CENTER FOR SPACE SCIENCES R A HEELIS JAN 87 1/1

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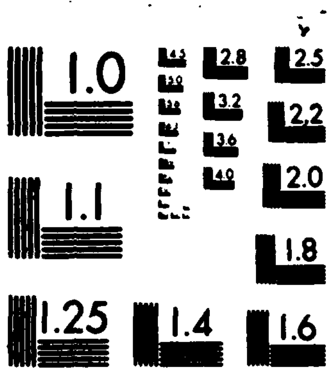

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A Collaborative Study of Plasma Irregularities From the HILAT Satellite

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Air Force Systems Command
United States Air Force
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Here we describe the technical and scientific accomplishments directed toward an understanding of the convective motion and evolution of high latitude plasma irregularities. ~~We have~~ principally utilized data from the retarding potential analyzer and the ion drift meter on board the HILAT satellite to determine the large scale convective motion of the plasma. In order to obtain this information it is necessary to recover the satellite attitude data so that corrections for the look angle of the sensor with respect to the satellite can be made. The properties of the satellite attitude variation are described and the procedures for reducing the instrument data to geophysical parameters are outlined. Data from successive overlapping contacts of the satellite from three high latitude stations are utilized to provide coverage of the entire high latitude region. Then derivation of the electrostatic potential distribution is used to describe the global convection pattern. The details of this pattern and its effect on the transport of irregularities from their source region to other locations is studied.

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FIGURE CAPTIONS

A Collaborative Study of Plasma Irregularities

from the HILAT Satellite.

ABSTRACT Here we describe the technical and scientific accomplishments directed toward an understanding of the convective motion and evolution of high latitude plasma irregularities. We have principally utilized data from the retarding potential analyzer and the ion drift meter on board the HILAT satellite to determine the large scale convective motion of the plasma. In order to obtain this information it is necessary to recover the satellite attitude data so that corrections for the look angle of the sensor with respect to the satellite can be made. The properties of the satellite attitude variation are described and the procedures for reducing the instrument data to geophysical parameters are outlined. Data from successive overlapping contacts of the satellite from three high latitude stations are utilized to provide coverage of the entire high latitude region. Then derivation of the electrostatic potential distribution is used to describe the global convection pattern. The details of this pattern and its effect on the transport of irregularities from their source region to other locations is studied.

INTRODUCTION

Our principle function during the HILAT mission has been to ensure the quality of the thermal plasma data, to derive the ambient ion drift velocity from the measured parameters and to participate in the interpretation of data obtained from the satellite instrument complement.

Following the launch of the HILAT satellite we devoted considerable effort to the design and implementation of a least squares algorithm for deriving the ion velocity along the satellite track and the ion temperature from the retarding potential analyzer characteristic curves. This algorithm was successfully utilized by the in-field processing scheme to provide data on the science summary tapes.

Several adjustments and augmentations to this procedure were made as a result of

HILAT RPA DAY 85052

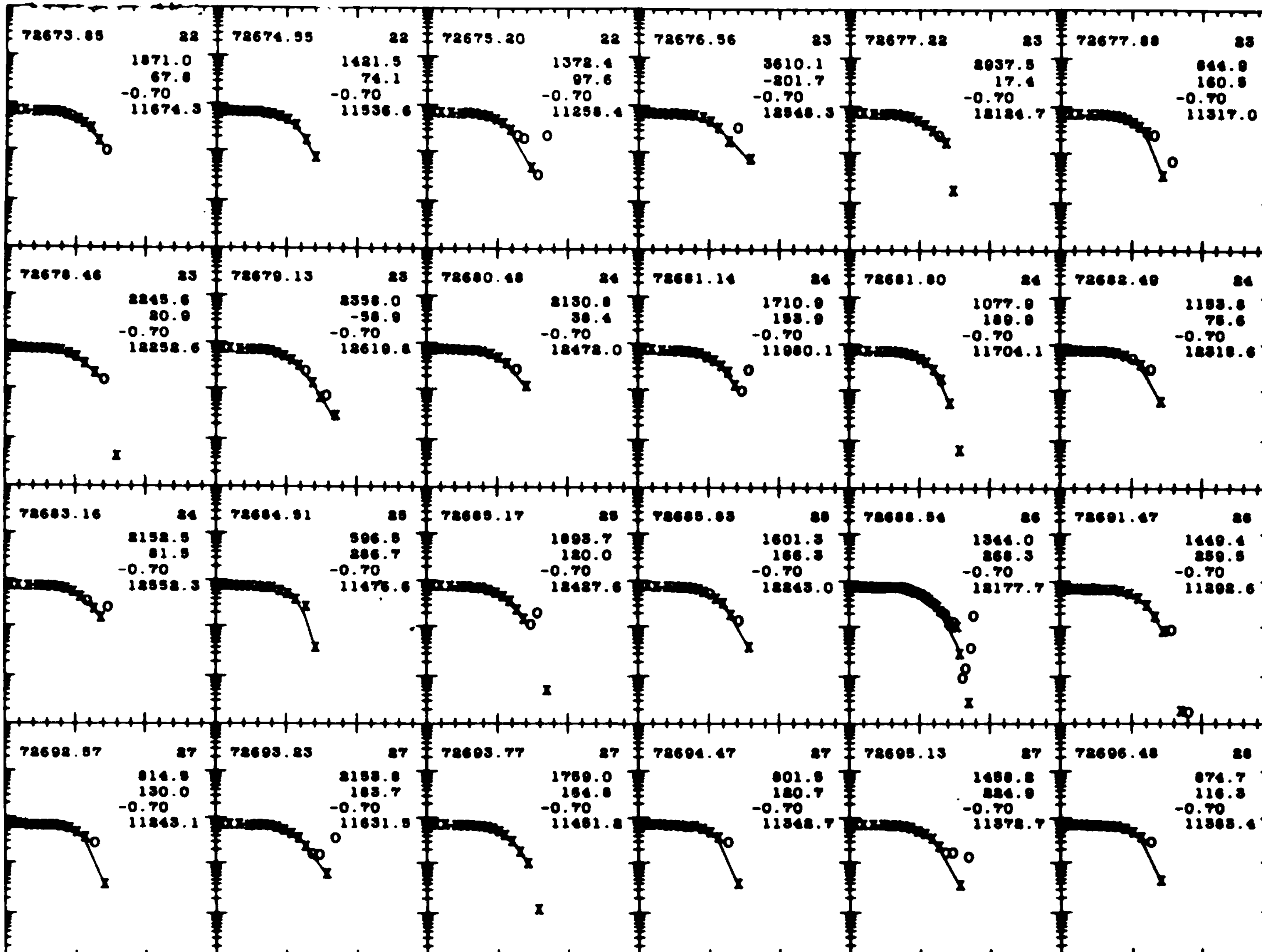


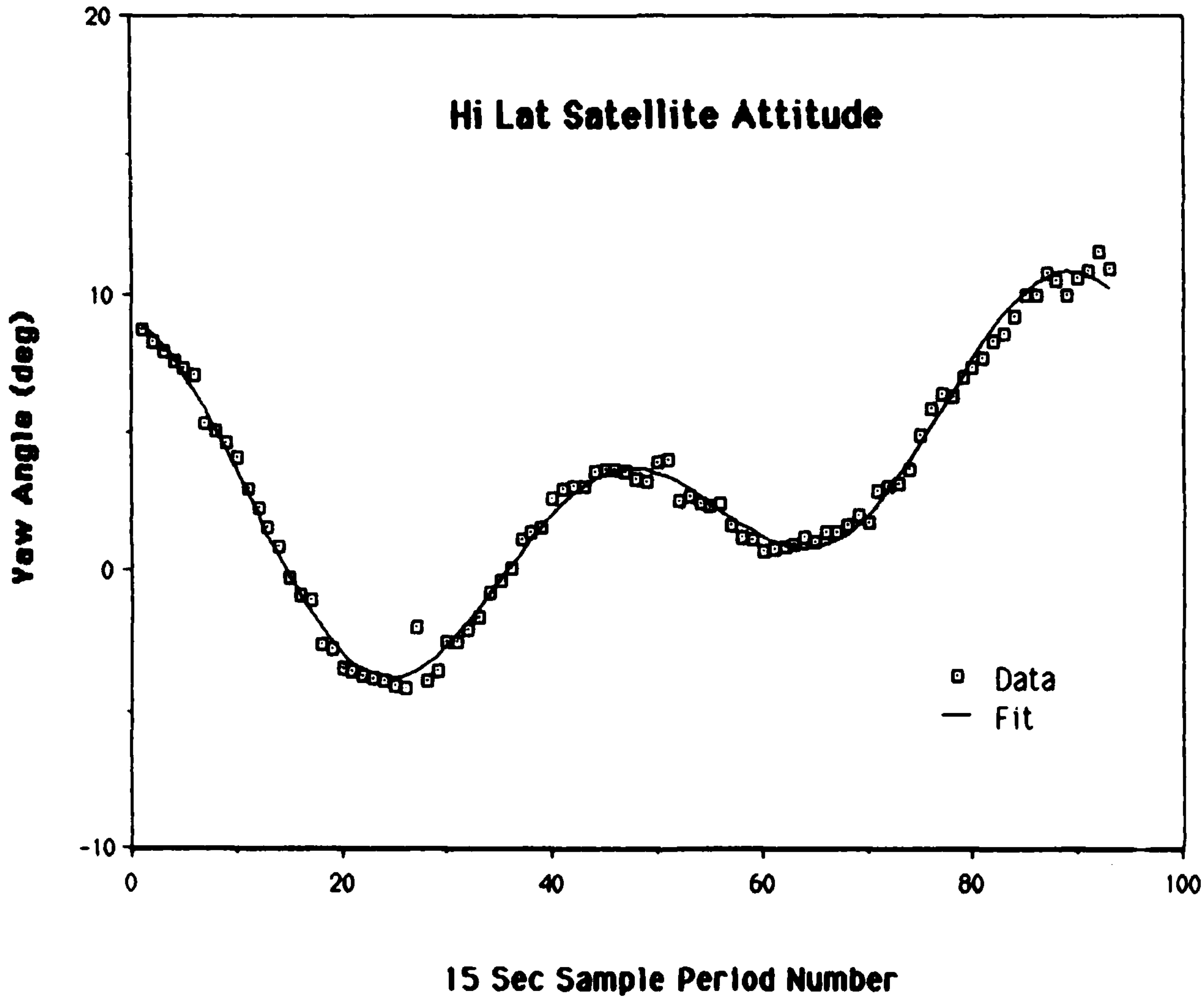
FIGURE 1

in plasma concentrations less than $10^4 cm^{-3}$. Figure 1 shows an example of the RPA characteristic curves obtained during Februrary 1985 over northern high latitudes. Four numbers to the right of each curve represent the ion temperature, the ion drift velocity, the spacecraft potential and the O^+ concentration, respectively derived from the least squares analysis. The routine involves an algorithm for removing erroneous point on the characteristic curve, which are denoted by 'O'. It can be seen that analysis of this data when the ion concentration exceeds $10^4 cm^{-3}$ yields relatively stable and good quality data for the drift velocity but a somewhat more variable and less reliable measure of the ion temperature. With this algorithm in place studies of the high latitude ionospheric convection pattern are possible provided the ambient ion drift velocity can be obtained from the ion arrival measurements of the ion drift meter. Our subsequent efforts were directed toward this goal.

SATELLITE ATTITUDE CORRECTIONS

Ambient ion drift velocity measurements from the ion drift meter can be obtained by removing the effects of vehicle attitude and atmospheric corotation from the signal. Since the orientation of the spacecraft is an extremely variable function with only sparse information available from the satellite data itself, considerable effort is required to extract the desired geophysical parameter. During the course of our research effort we have pursued two approaches to this problem. The first is a derivation of the satellite orientation by fitting the derived attitude data from the spacecraft to a smooth function. The second, is to derive the attitude by requiring the ion drift signal below magnetic latitudes of about 50° to represent only the signal due to atmospheric corotation.

These two approaches can be contrasted by first considering the data in figure 2 taken during a pass over the summer northern hemisphere. Here is shown the spacecraft yaw angle determined from the attitude determination algorithms applied to consecutive contacts of the satellite by Churchill, Sondrestrom, and Tromso. The data are plotted versus sample number, a sample being taken every 15 seconds. The symbol A denotes the derived yaw angle while P denotes the predicted value obtained from a sophisticated non-linear optimization technique. This technique produces an excellent fit to the data utilizing



Hi Lat Satellite Attitude
Yaw Angle (deg)
20
10
0
-10
0
20
40
60
80
100
Data
Fit
15 Sec Sample Period Number

FIGURE 2

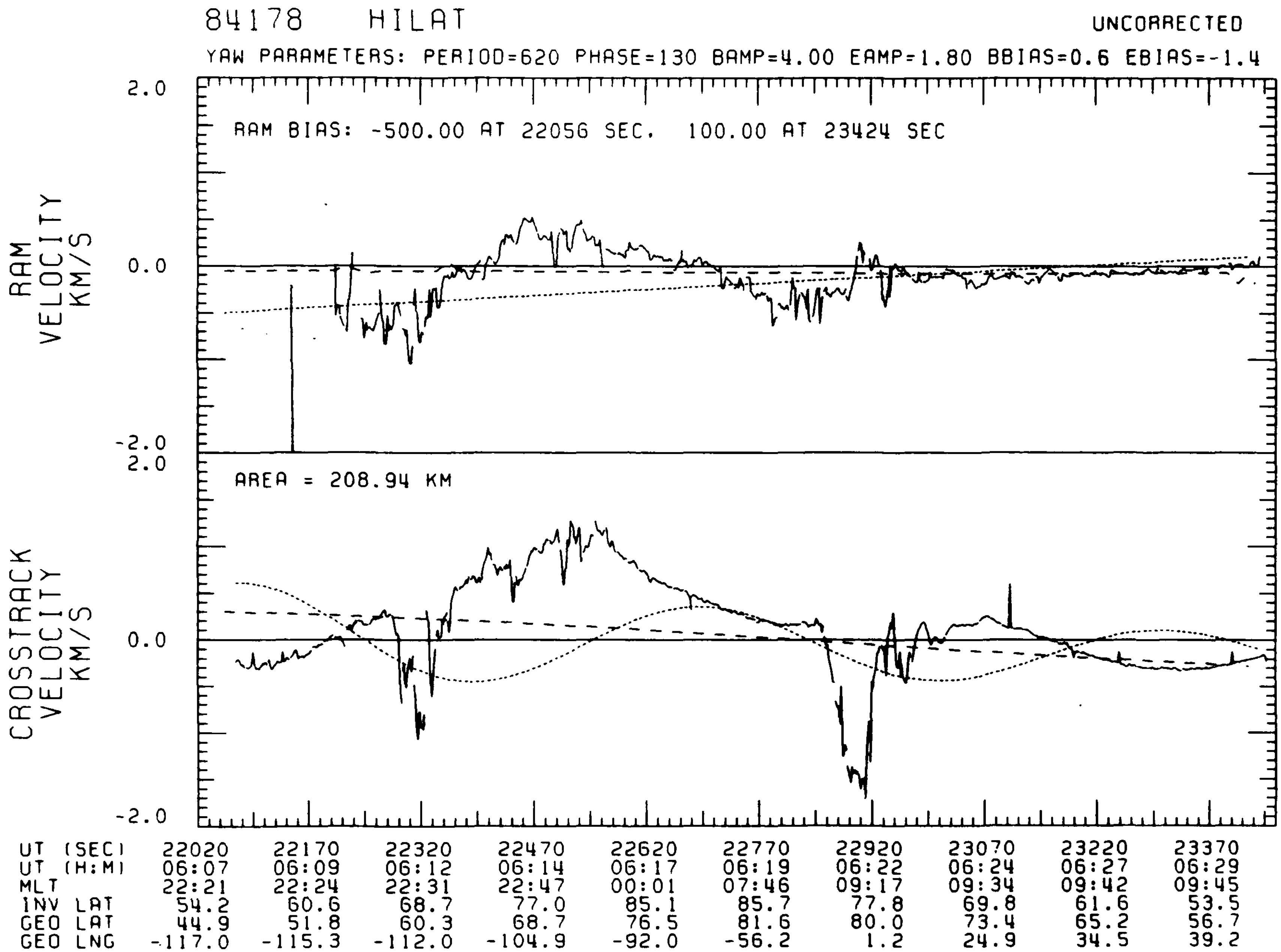
only two wave forms with periods of approximately 680 and 1500 seconds and amplitudes of 3.7° and 4.1° respectively. It was found that insufficient data was available from a single station contact to confidently derive the wave forms in the yaw angle but optimal values for the phase and amplitude of a wave form with period 680 seconds could be determined. Despite the accuracy with which this data can be modelled, the amplitudes and periods of the waveforms produce values of the ambient ion drift velocity that are difficult to reconcile with the electrodynamic drifts known to exist in the plasmasphere.

This can be readily seen by examining the uncorrected data from this pass shown by the solid curves in figure 3. The lower panel shows the ion arrival angle measured by the ion drift meter, expressed as an ion drift velocity perpendicular (crosstrack) to the satellite track. The dominant ion species throughout the orbit is O^+ and for the orbital velocity of this spacecraft the ion arrival angle may be converted to ion velocity using the approximate relation

$$1^\circ = 130 m.s^{-1}.$$

Referring to the end of the Tromso contact near 23370 secs we see that the observed ion velocity is approximately 350 $m.s^{-1}$ corresponding to an ion arrival angle near 3°. Inspection of the attitude angle at this time from figure 2 shows that the derived angle is near 11°. This 7 or 8 degree difference in the two angle measurements can only be eliminated by invoking an ion drift of about 1 $km.s^{-1}$ in the latitude region below 50°. With the possibility that this difficulty reflects an error in the attitude determination itself, we have pursued alternative approaches to correcting the cross track ion drift velocity. One approach is illustrated by again examining figure 3. In addition to the uncorrected data, shown by the solid trace in the lower panel we have also plotted, using a long dashed line, the component of atmospheric corotation that we expect the ion drift meter to measure. We have then asked the question "What single period wave form with a linearly varying amplitude would be required to match the drift meter signal at invariant latitudes less than 60° to the corotation velocity?". Using a controlled iterative technique we calculate the wave form shown by the short dashed curve.

This wave form is compared to the derived spacecraft attitude angle, calculated from the magnetometer data alone, in figure 4. Here the solid line denotes the derived attitude angle which overlaps itself where two stations make simultaneous contact with the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RAM VELOCITY KM/S
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0.0
-2.0
AREA = 208.94 KM
CROSSTRACK VELOCITY KM/S
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0.0
-2.0
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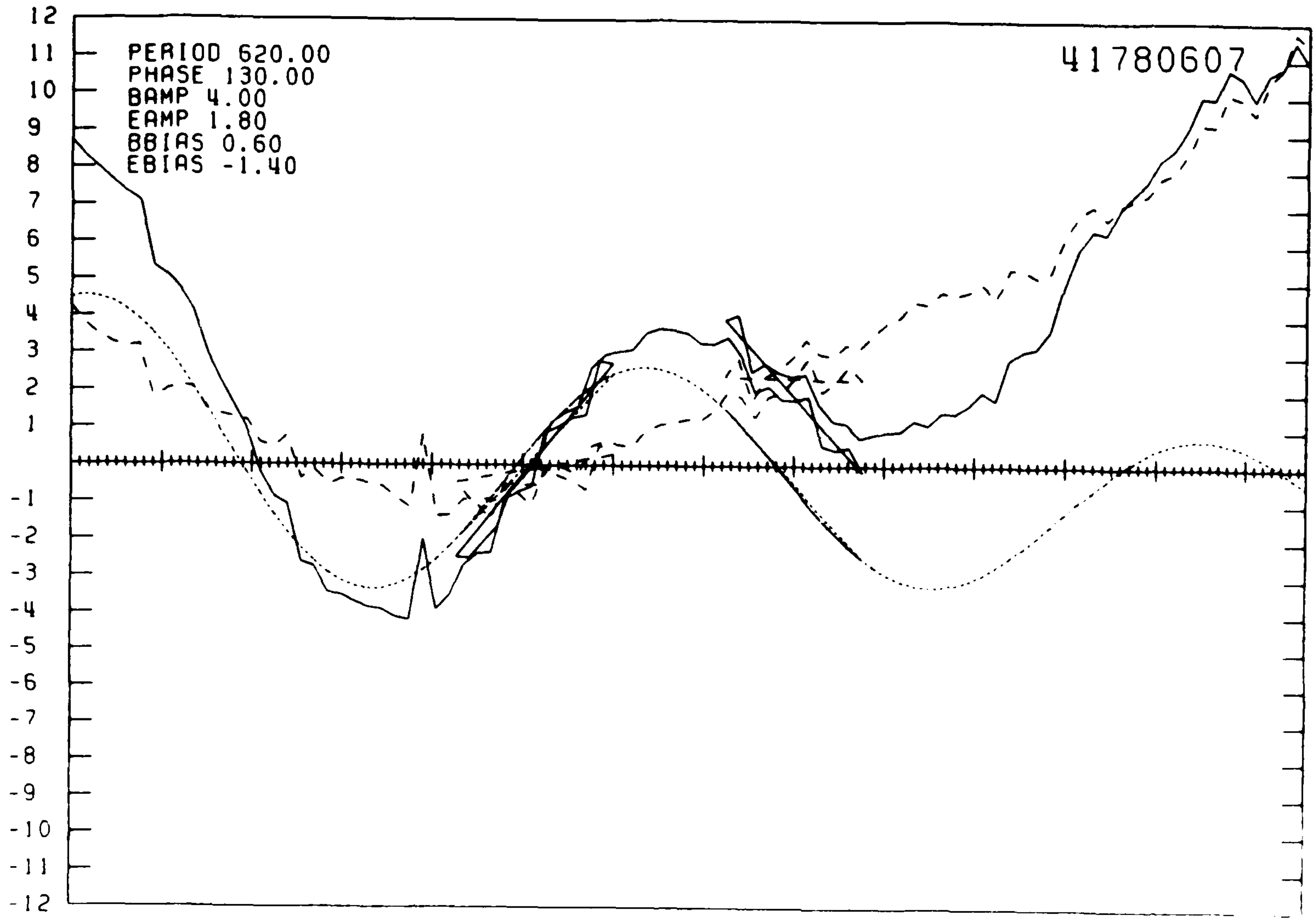
UT (H:M) 06:07 06:09 06:12 06:14 06:17 06:19 06:22 06:24 06:27 06:29
MLT 22:21 22:24 22:31 22:47 00:01 07:46 09:17 09:34 09:42 09:45
INV LAT 54.2 60.6 68.7 77.0 85.1 85.7 77.8 69.8 61.6 53.5
GEO LAT 44.9 51.8 60.3 68.7 76.5 81.6 80.0 73.4 65.2 56.7
GEO LNG -117.0 -115.3 -112.0 -104.9 -92.0 -56.2 1.2 24.9 34.5 39.2

FIGURE 3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3
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-2
-3
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-5
-6
-7
-8
-9
-10
-11
-12

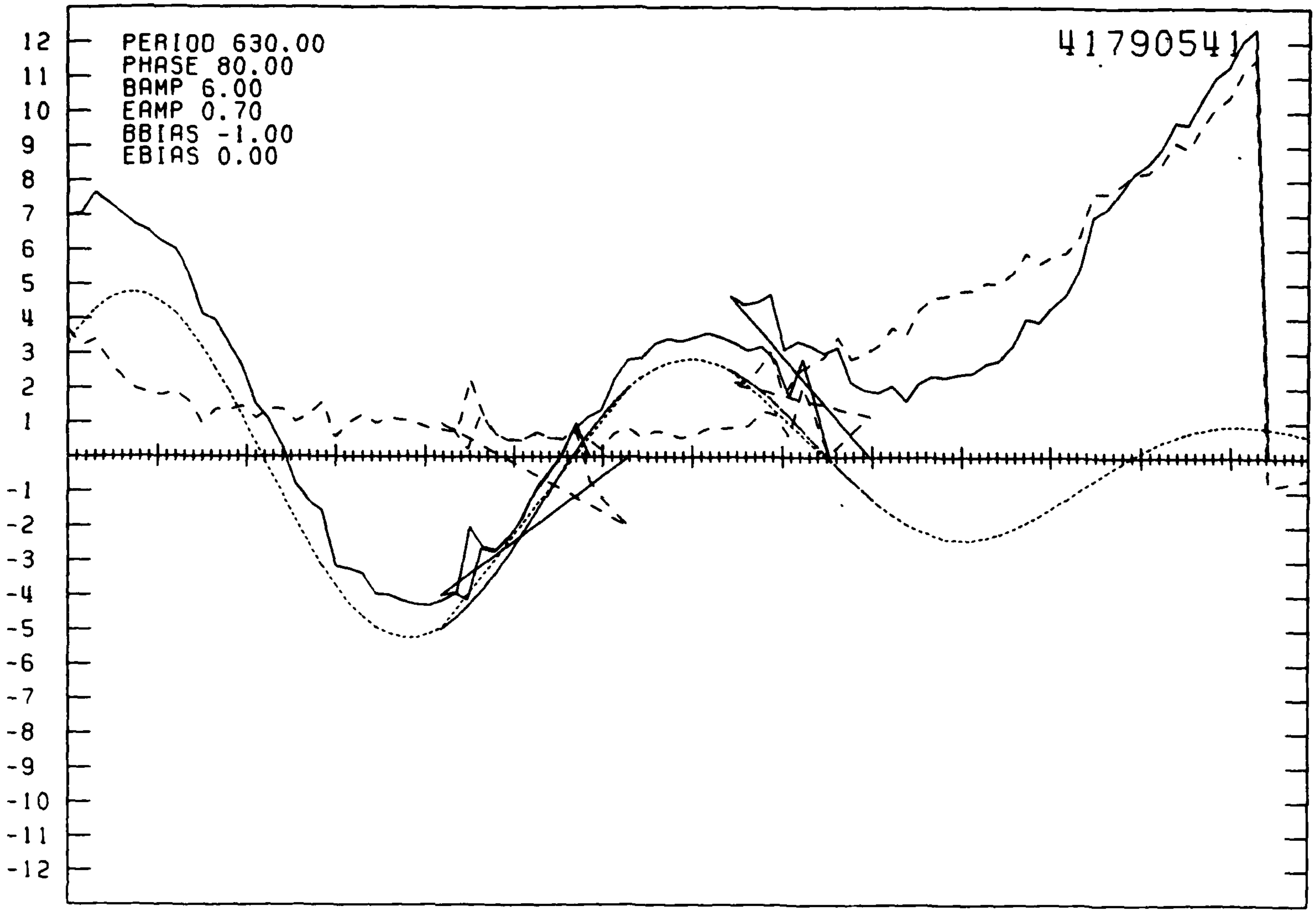
FIGURE 4

spacecraft. The short dashed line is the waveform calculated by forcing the signal to match corotation inside the plasmasphere and the long dashed line is the difference between the two. We note that with modest changes in the phase of this single wave form we can easily reconcile the period of 620 s with the previously derived period of 680 s. We also note that relatively good agreement between the two techniques can be obtained at high latitudes. Note however that a large discrepancy exists at the low latitude extremes of the data set where we expect the measured ion arrival angle to be close to the attitude angle but in fact they are quite different.

This trend appears to be quite reproducible during this time period as evidenced by a further example shown in figure 5. Here consecutive contacts of the spacecraft were made on the following day and a plot in the same format as that in figure 4 shows similar characteristics. Note that a fundamental wave form near 680 s is again calculated but as before a large discrepancy between the techniques exists in the low latitude portions of the orbit. We have pursued the 'corotation correction technique' a little further with the desire to examine the possible convection pattern that might exist during this time and with the hope that the derived electrostatic potential distribution may shed more light on the problem.

The results of this approach can be seen by further examination of figure 6. Here the data from figure 3 have been corrected for spacecraft attitude by forcing the signal to correspond to the atmospheric corotation velocity inside the plasmasphere. That this has been successfully achieved can be seen by noting the agreement between the data (solid line) and the corotation velocity (dashed line) at the two low latitude ends of the pass.

Finally in figure 7 we show the ambient ExB velocity obtained by subtracting the corotation velocity from the attitude corrected data. A clear signature of a two-cell convection pattern is seen and integration of this signal along the satellite track to derive the electrostatic potential gives a potential difference from 06 08 UT to 06 29 UT of less than 20 kilovolts. We believe that this is an acceptable error considering the uncertainties in the derived ion drift velocity. Considerably larger errors result from using the attitude data derived solely from the satellite magnetometer.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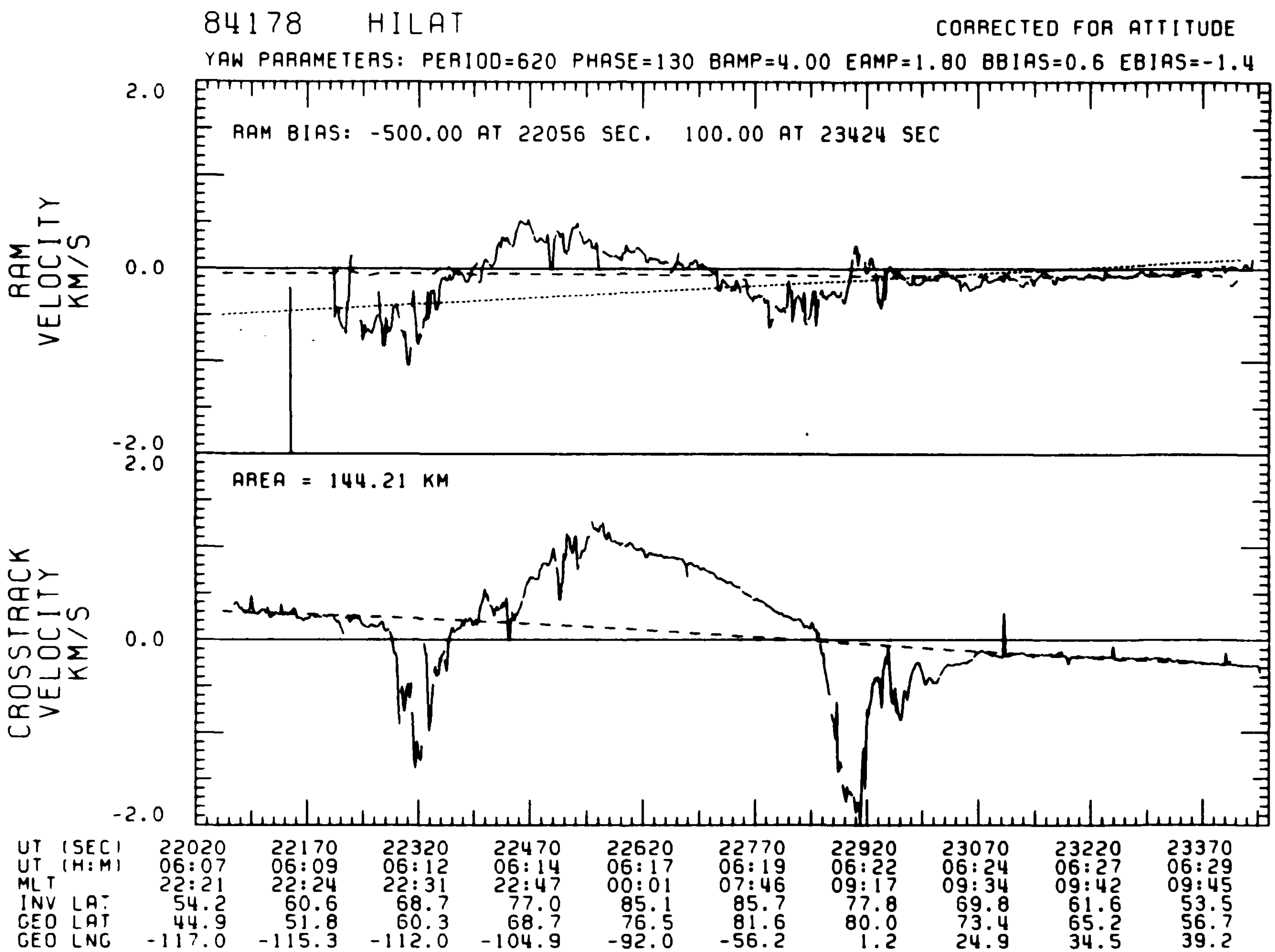
-10
-11
-12

FIGURE 5



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RAM VELOCITY KM/S
CROSSTRACK VELOCITY KM/S
2.0
0.0
-2.0
2.0
0.0
-2.0
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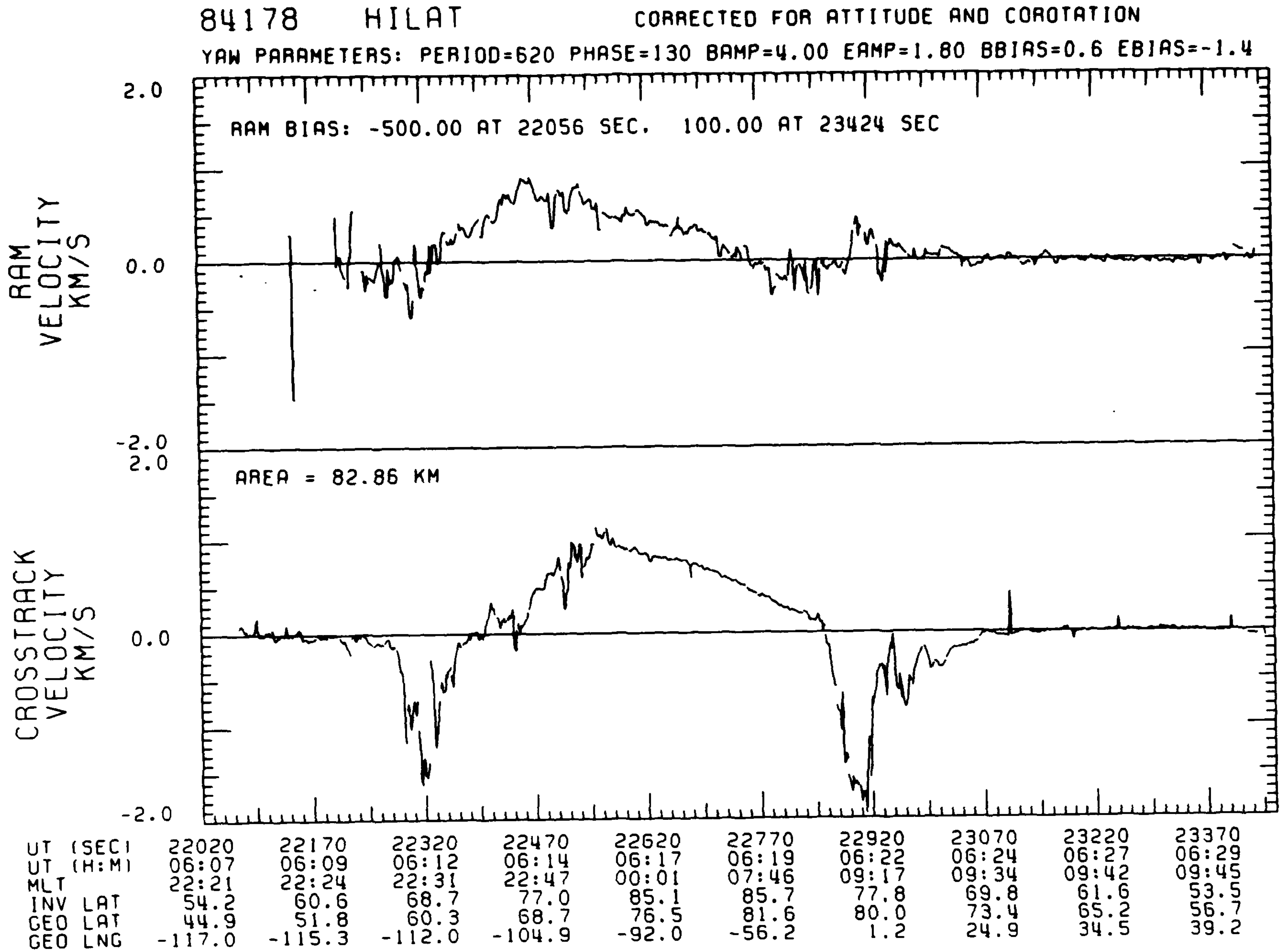
UT (H:M) 06:07 06:09 06:12 06:14 06:17 06:19 06:22 06:24 06:27 06:29
MLT 22:21 22:24 22:31 22:47 00:01 07:46 09:17 09:34 09:42 09:45
INV LAT 54.2 60.6 68.7 77.0 85.1 85.7 77.8 69.8 61.6 53.5
GEO LAT 44.9 51.8 60.3 68.7 76.5 81.6 80.0 73.4 65.2 56.7
GEO LNG -117.0 -115.3 -112.0 -104.9 -92.0 -56.2 1.2 24.9 34.5 39.2

FIGURE 6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CROSSTRACK VELOCITY KM/S
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-2.0
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INV LAT 54.2 60.6 68.7 77.0 85.1 85.7 77.8 69.8 61.6 53.5
GEO LAT 44.9 51.8 60.3 68.7 76.5 81.6 80.0 73.4 65.2 56.7
GEO LNG -117.0 -115.3 -112.0 -104.9 -92.0 -56.2 1.2 24.9 34.5 39.2

FIGURE 7

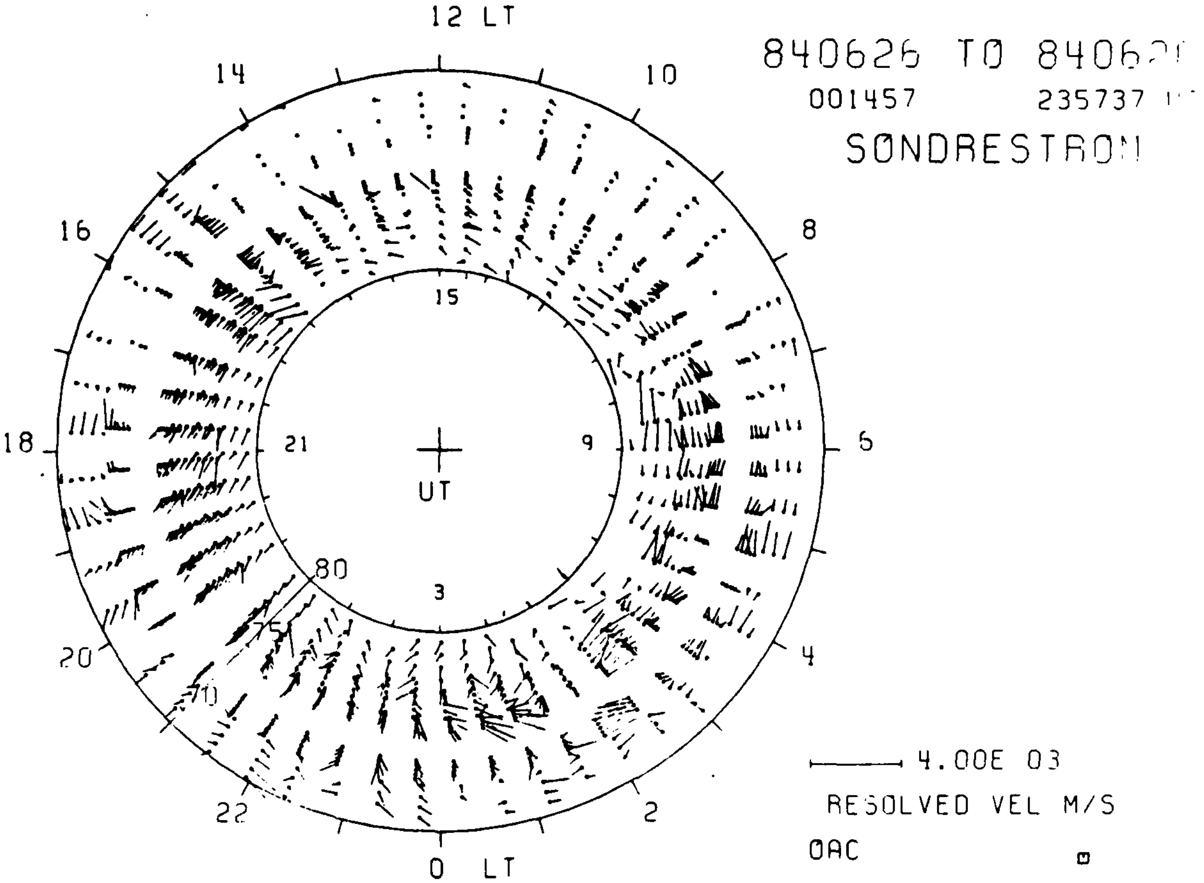
IONOSPHERIC CONVECTION PATTERNS

This orbit and a series of passes during this period were selected for study due, not only to the favorable ionospheric conditions but also to the fact that ion convection data from the Sondrestrom radar are also available during this period. We are thus in a unique position to assemble a more complete view of the high latitude convection pattern from the combined data sets.

Figure 8 shows two polar dials containing the ion convection velocities measured by the Sondrestrom radar during days 84178 and 84179 when several contacts of the HILAT satellite were made by all three of the northern hemisphere high latitude stations. Measurements are made in the invariant latitude range from 69° to 80°, approximately every 25 minutes. During about a 25 minute period the HILAT satellite makes a complete pass across the northern high latitude region. Our objective in this study has been to combine simultaneous measurements from the satellite and the radar to provide a more realistic description of the convection pattern than would be available from a single data source.

Figure 9 shows the ionospheric convection pattern signature obtained from the HILAT satellite and the simultaneously measured latitude scan of the radar extracted from figure 8. Several inferences can be drawn from these data. First note that the convection reversal near $\Lambda \doteq 80°$ and 0900 hrs magnetic local time (MLT) is of the rotational type such that antisunward polar cap flow makes a transition to sunward flow in the dawnside auroral zone. Second, we note that the satellite data indicate the zero potential line that divides the two-cells in the observed pattern is located on the satellite track at the same MLT as the latitude scan of the radar. The data from the radar show that the ion velocity changes direction during the scan. It however, generally indicates an equatorward and westward component at high latitudes and a more eastward component at lower latitudes. Such a signature is consistent with a convection reversal in the dawn cell located near $\Lambda = 73°$. By comparing the electrostatic potential distribution along the radar track with that along the satellite track we are able to construct the most likely self consistent convection paths for the plasma. Significant deviations from the implied circular geometry of the dawn cell on day 84178 exist on the following d?

An example of the combined radar and satellite data during this period when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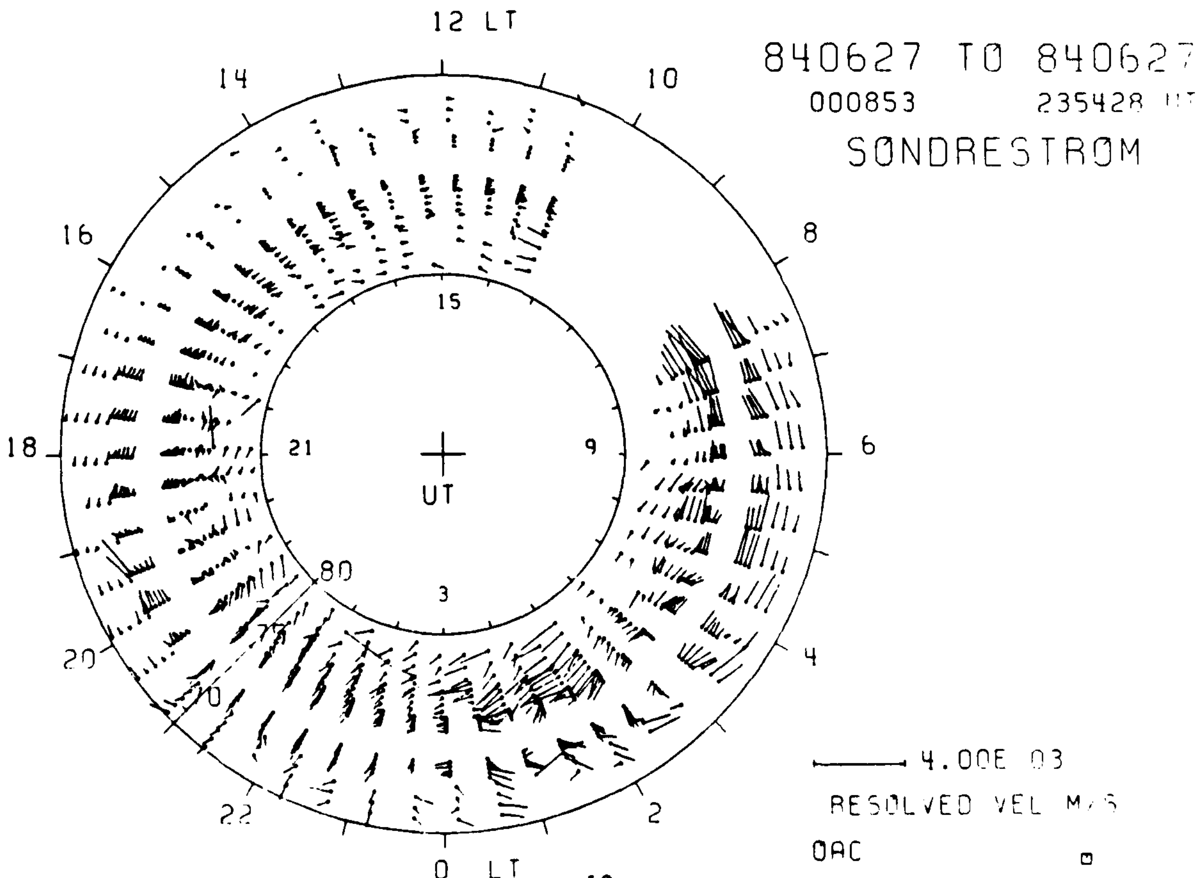
4.00E 03
RESOLVED VEL M/S
OAC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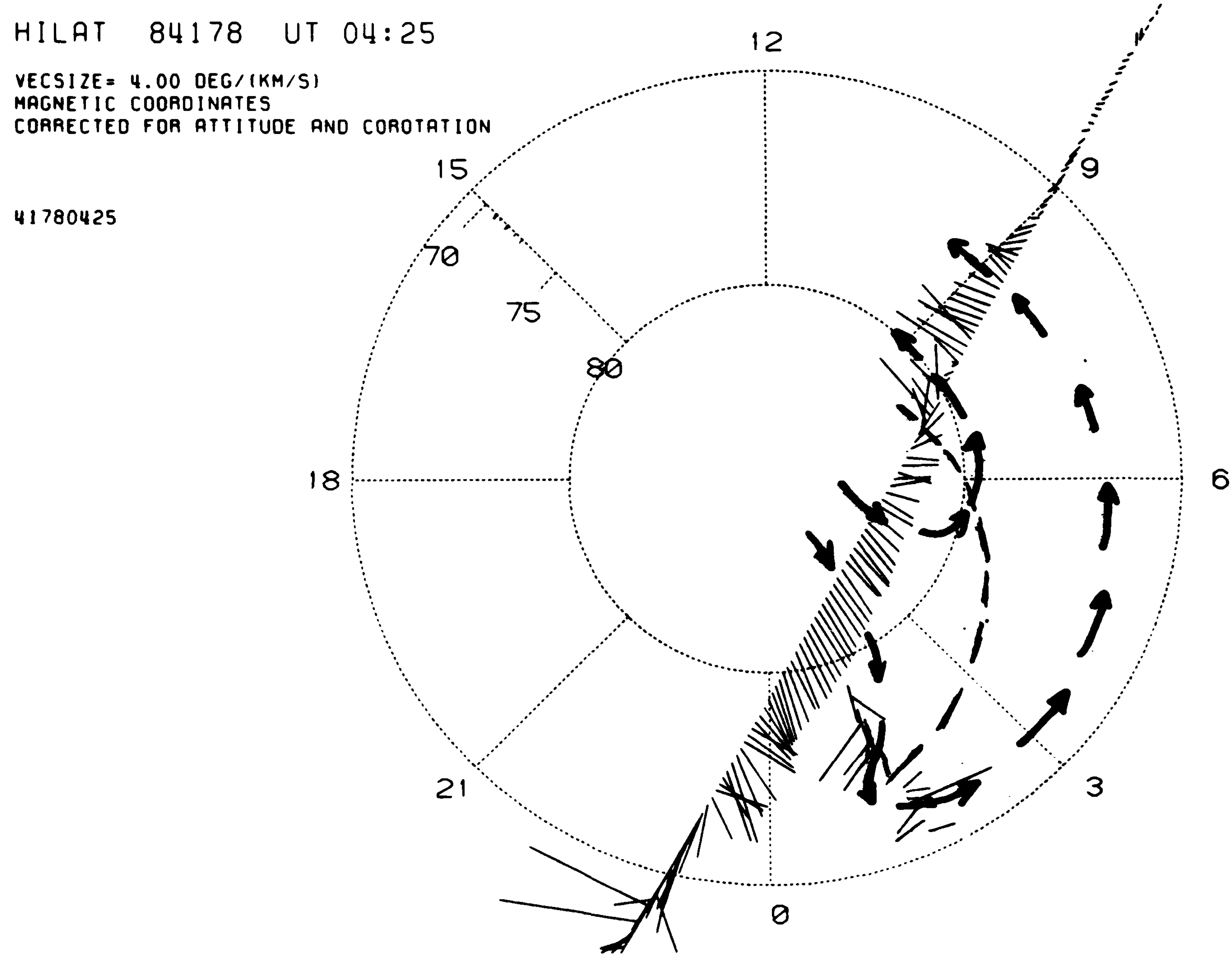
RESOLVED VEL
OAC

FIGURE 8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18
6
21
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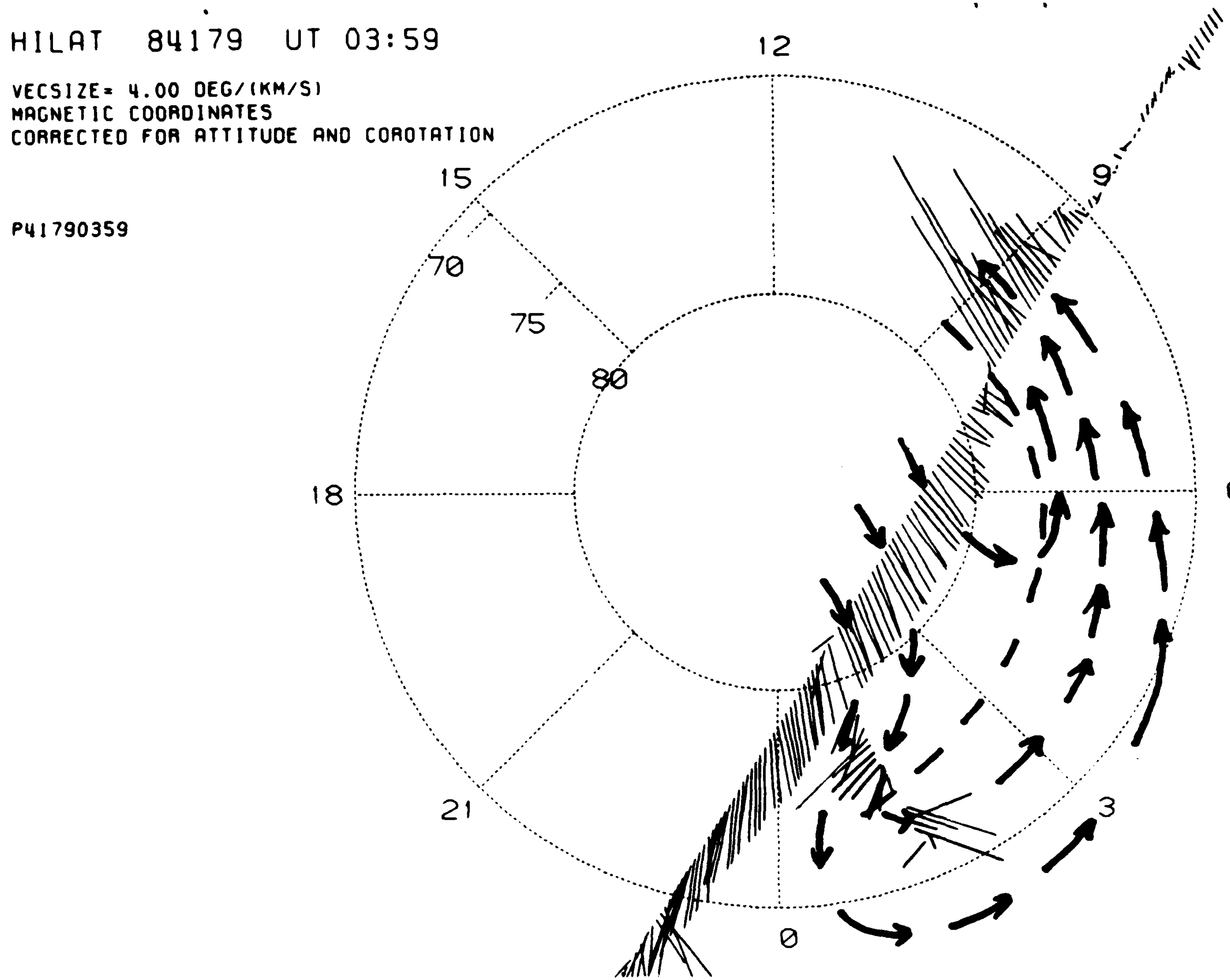
FIGURE 9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18
21
0
3
6
9
70
75
80

FIGURE 10

the IMF B_y component was positive is shown in figure 10. Clearly more work on the precise relationship between the potential distributions derived from the satellite data and the radar data are required before the most realistic convection patterns can be identified. This work is nearing completion and will be submitted for publication in the near future.

In addition to the major task of deriving drift velocity data of sufficient quality to derive the convection pattern itself we have also collaborated with scientists from other institutions in interpretation of small scale structure in the drift velocity with scale sizes much smaller than variations produced by the satellite oscillations. Findings on the magnitude and power in this structure is thus not greatly affected by the uncertainty in the absolute value of the drift.

We have examined the relationship between structure in the ion drift velocity and the magnetic field-aligned currents in the scale size range of 3 km to 80 km. It is found that the ion drift velocity, or equivalently, the electric field structure shows a strong seasonal dependence. It has much larger amplitudes in the winter hemisphere when the ionospheric conductivity is low, than in the summer hemisphere when the conductivity is much higher. The field-aligned currents show no such seasonal dependence in the scale size regime considered. It is thus likely that at these scale sizes the magnetosphere behaves much like a current generator.

Another relationship between quasi-periodic structure in the field-aligned current and ion drift signatures was examined with a view to its possible relationship to processes in the low-latitude boundary layer where the region 1 currents are thought to originate. In this study the wavelength and electrostatic potential at the HILAT satellite were found to be consistent with the expected wavelength for waves in the boundary layer. It was also found that the appearance of energetic precipitating electrons with acceleration energies of a few kilovolts is consistent with the mapping of the boundary layer waves to the ionosphere.

PUBLICATIONS

Support from this grant has allowed our collaboration in the following publications.

F.J. Rich, R.A.Heelis, W.B. Hanson, P.B. Anderson, B.J. Holt, L.L. Harmon, D.R. Zucarro,

C.R. Lippincott, D. Girouard, and W.P. Sullivan, Cold plasma measurements on HILAT, *ALP Tech. Dig.*, *5*, 114-119, 1984.

P.F. Bythrow, T.A. Potemra, L.J. Zanetti, C.-I. Meng, R.E. Huffman, W.B. Hanson, F.J. Rich, and D.A. Hardy, Earthward directed high-density Birkeland currents observed by HILAT, *J. Geophys. Res.*, *89*, 9114-9118, 1984

E.J. Fremouw, H.C. Carlson, T.A. Potemra, P.F. Bythrow, C.L. Rino, J.F. Vickrey, R.L. Livingston, R.E. Huffman, C.-I. Meng, D.A. Hardy, F.j. Rich, R.A. Heelis, W.B. Hanson, and L.A. Wittwer, The HiLat satellite mission, *Radio Sci.*, *20*, 416-424, 1985.

J.F. Vickrey, R.C. Livingston, N.B. Walker, T.A. Potemra, R.A. Heelis, M.C. Kelley and F.J. Rich, On the current-voltage relationship of the magnetospheric generator at intermediate spatial scales, *Geophys. Res. Lett.*, *13*, 495-498, 1986.

P.F. Bythrow, M.A. Doyle, T.A. Potemra, L.J. Zanetti, R.E. Huffman, C.-I. Meng, D.A. Hardy, F.J. Rich, and R.A. Heelis, Multiple auroral arcs and Birkeland currents: evidence for plasma sheet boundary waves, *Geophys. Res. Lett.*, *13*, 805-808, 1986.

R.A. Heelis, J.F. Vickrey, W.B. Hanson, and F.J. Rich, Satellite and ground based observations of large scale high latitude convection patterns, *J. Geophys. Res.*,, to be submitted, 1987.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 89, NO. A10, PAGES 9114-9118, OCTOBER 1, 1984

Earthward Directed High-Density Birkeland Currents Observed by HILAT

P. F. BYTHROW,[1] T. A. POTEMRA,[1] W. B. HANSON,[2] L. J. ZANETTI,[1] C.-I. MENG[1] R. E. HUFFMAN,[3]
F. J. RICH,[3] and D. A. HARDY[3]

An intense (94 $\mu A/m^2$) earthward directed Birkeland current was detected by the HILAT satellite on July 23, 1983, less than one month after launch. It was located at the equatorward edge of a large-scale earthward flowing current in the late evening sector. This current is the most intense ever to be reported that is consistent with upward flowing thermal electrons. Simultaneous vacuum ultraviolet images from the auroral imager mapper show that the large-scale current is embedded within the diffuse aurora. Energetic electron measurements in the range 20 eV to 20 keV indicate an increase in downward flux from $\sim 5 \times 10^7$ to $\sim 7 \times 10^9$ (cm^2 sec sr)$^{-1}$ in ~ 0.75 s. This increase in flux results in a gradient of ~ 2 mhos/km in the height-integrated Pedersen conductivity (Σ_p). In the presence of a typical dc electric field (~ 40 mV/m), this sharp gradient in the ionospheric conductivity is consistent with the inferred high-density current. Measurement of horizontal ion drift from the ion drift meter (IDM) reveals strong turbulence present for ~ 10 km on both sides of the region of intense Birkeland current. The IDM also measured an ion density (n_i) of $\sim 2 \times 10^4$ cm^{-3}; thus, if $n_e = n_i$, the parallel electron drift velocity derived from $J = n_e V_d q$ is ~ 30 km/s, resulting in a net electron flux of $\sim 6 \times 10^{10}$ cm^{-2} s^{-1}. A flux of electrons of this magnitude is sufficient to destabilize O^+ ion cyclotron waves. The velocity of 30 km/s coupled with an F region ion density gradient scale length of ~ 3 km is also comparable to criteria required to drive the current convective instability.

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The HiLat satellite mission

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On June 27, 1983, USAF satellite P83-1 was launched from Vandenberg Air Force Base carrying the five ionospheric-effects and diagnostic payloads of DNA's HiLat satellite mission. A Scout launch vehicle placed the satellite in an 800-km circular orbit at an inclination of 82°. The HiLat experiments are as follows: (1) a VHF/UHF/*L* band coherent radio beacon for observing complex-signal scintillation and total electron content; (2) a three-instrument cold-plasma package for measuring number density and temperature, their spatial fluctuations, and plasma convection velocity and its fluctuations; (3) an electron spectrometer for detection of precipitating and upwelling electrons with energies between 20 eV and 20 keV; (4) a three-axis magnetometer; and (5) an optical assembly for imagery and spectrophotometry in the vacuum-ultraviolet spectrum and for photometry at two visual wavelengths. With the exception of partial launch damage to the electron sensor (Langmuire probe) in the cold-plasma package, all payloads initially operated as designed. After approximately 40 orbits of data collection, however, the imaging spectrophotometer failed. In spite of this failure, the optical instrument proved the concept of imaging the aurora, at vacuum-ultraviolet wavelengths, under conditions of full sunlight. Its visual-wavelength photometers continue to perform well, as do the other four HiLat payloads. This paper presents early observations from HiLat.

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ON THE CURRENT-VOLTAGE RELATIONSHIP OF THE MAGNETOSPHERIC GENERATOR AT INTERMEDIATE SPATIAL SCALES

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Abstract. Using data from the drift meter and magnetometer on board the HILAT satellite, we have examined fluctuations in high latitude electric and magnetic fields at scale sizes between 80 km and 3 km. A comparison of data from summer and winter allows us to assess the impact of changing ionospheric conductivity on the magnetospheric generator. We find that, at these scale sizes, the magnetosphere tends to behave as a constant current source that is independent of ionospheric conductivity. This characteristic was noted on both open and closed field lines. The electric field pattern, on the other hand, is much more highly structured in the winter than in the summer. This behavior implies scale size dependent potential drops on closed field lines.

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MULTIPLE AURORAL ARCS AND BIRKELAND CURRENTS: EVIDENCE FOR PLASMA SHEET BOUNDARY WAVES

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Abstract. Quasi-periodic structures of small-scale Birkeland currents, energetic electrons, ion drifts, and auroral forms in the dawn sector have been observed simultaneously with the HILAT spacecraft. These structures map to the Low Latitude Boundary Layer using a model geomagnetic field. This mapping is supported by the observed characteristics of the energetic electrons and the relationship between precipitating electrons, Region 1 Birkeland currents, and plasma drift. These observations are interpreted as the result of quasi-periodic variations of the Low Latitude Boundary Layer. Values of potential, estimated from assumed characteristics of a large-scale wave propagating in this layer, agree with those determined from the HILAT particle and drift measurements. These results support the view that wave propagation at the Low Latitude Boundary Layer/Plasma Sheet interface can be a source of multiple auroral forms at low altitudes. We suggest that the Kelvin-Helmholtz instability may be the ultimate source of these waves.

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